Fabrication and Performance of Thin-Film YSZ SOFCs between 600 and $800^{O}C$

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Current thin-film yttria-stabilized zirconia (YSZ) electrolyte cell fabrication techniques require sintering the YSZ electrolyte on a NiO-YSZ composite substrate at temperatures in the vicinity of 1400°C. These high sintering temperatures have prevented the development of new electrode designs and materials such as cathode-supported thin-film YSZ cells and Cu-YSZ composite anodes in reduced-temperature SOFCs.

In this paper we report a new low-cost technique for the fabrication of thin-film YSZ on porous NiO-YSZ and $La_xSr_{1-x}MnO_3$ (LSM–YSZ) composite substrates using aqueous YSZ-powder suspensions. The technique has been used to fabricate planar thin-film YSZ fuel cells. The YSZ sintering temperatures are below 1300°C, and the thickness of the YSZ electrolyte is between 3 and 10 µm. The electrolyte is strongly bonded to the NiO-YSZ and LSM-YSZ substrates. As shown in Figure 1, the thin film is dense and smooth.

The performance of a Ni-YSZ supported Ni-YSZ/YSZ/LSM-YSZ cell at 600 to 800°C, with air as the oxidizer and H_2-3% H_2O as the fuel is shown in Figure 2. Due to the good bonding between the thin-film YSZ electrolyte and the electrodes, the area specific resistance (ASR) is 0.071 Ω.cm at 800°C. The cell power density is 0.85, 0.42 and 0.14 W/cm^2 at 800°C, 700°C and 600°C, respectively.

In this paper, we also report thin-film YSZ cell performances with mixed conducting doped-YSZ electrodes, and our initial results of a Cu-YSZ anode for the dry oxidation of methane (CH_4). Initial investigations of doped-YSZ mixed-conducting electrodes in our YSZ thin-film cells indicate that Tb- and Ti-doped YSZs can increase power densities from 15% to 50% at 800°C. Thus our initial results indicate that mixed-conducting doped-YSZs can improve significantly cell performance.

Our initial experiments for new anodes for the direct oxidation of methane have used thick YSZ (230µm) electrolytes. As shown in Figure 3, the Ni-YSZ anode quickly dies in dry CH_4, and switching back to H_2 has no effect on the anode. However the Cu-YSZ anode has a unique performance in dry methane. The power density decreases on switching from H_2 to methane fuel, and then recovers back when the fuel is switched back to H_2. The performance of the Cu-YSZ anode is stable and no carbon deposition is observed after long-term operation, and it is a promising anode for direct oxidation of methane fuel cells.

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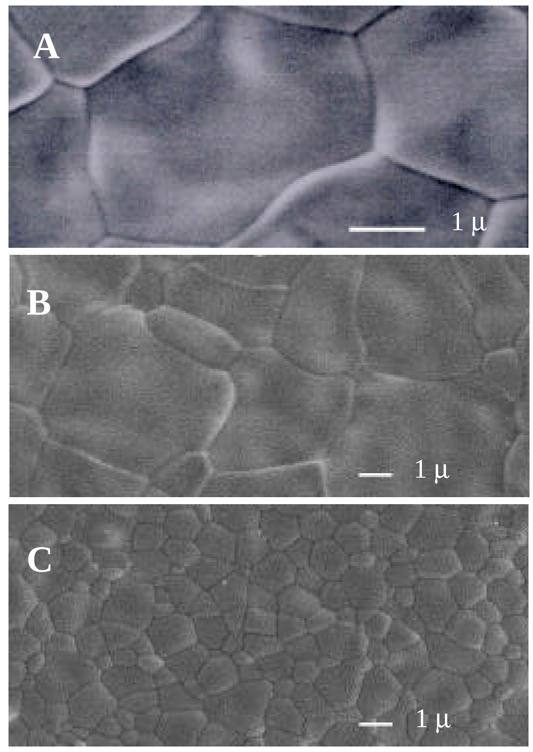

Figure 1. SEM Micrograph of YSZ Electrolyte
A. 1400°C sintered on NiO-YSZ Substrate
B. 1300°C Sintered on LSM-YSZ Substrate
C. 1200°C Sintered on LSM-YSZ Substrate

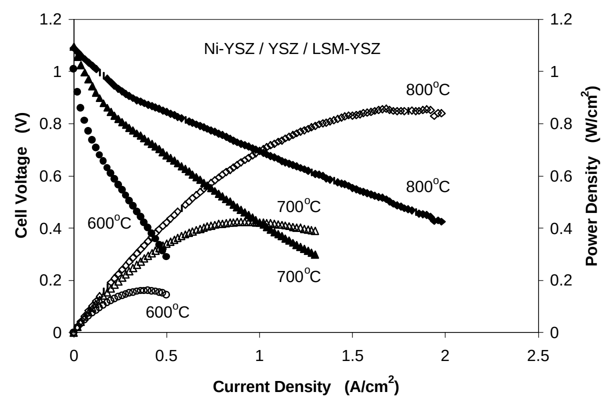

Figure 2. Ni-YSZ/YSZ/LSM-YSZ Cell Performance at 800°C, 700°C, and 600°C

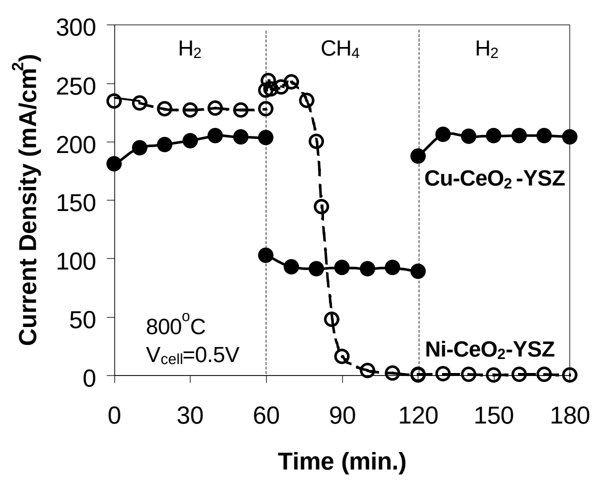

Figure 3. Changes of Current Densities at Different Fuel Gases of Thick Film YSZ Cells with Different Anodes